

4. Nitrous Oxide Emissions

Overview

U.S. Anthropogenic Nitrous Oxide Emissions, 1990-2002

	Nitrous Oxide	Carbon Dioxide Equivalent
Estimated 2002 Emissions (Thousand Metric Tons)	1,125.2	333,056
Change Compared to 2001 (Thousand Metric Tons)	-13	-3,721
Change from 2001 (Percent)	-1.1%	-1.1%
Change Compared to 1990 (Thousand Metric Tons)	-2.6	-777
Change from 1990 (Percent)	-0.2%	-0.2%

Estimated U.S. anthropogenic nitrous oxide emissions totaled 1,125 thousand metric tons in 2002, 1.1 percent less than in 2001 and 0.2 percent below 1990 levels (Table 23). Almost all of the decrease from 2001 can be attributed to nitrogen fertilization of agricultural soils. Emissions from this source decreased by 16 thousand metric tons of nitrous oxide compared with 2001 levels. Emissions of nitrous oxide from industrial sources in 2002 increased by 3 thousand metric tons from their 2001 level.

The decrease in emissions of nitrous oxide from 1990 can be attributed to emissions from nitrogen fertilization of agricultural soils and industrial sources (adipic acid and nitric acid production), which fell by a combined 67 thousand metric tons between 1990 and 2002, more than offsetting the increase of 59 thousand metric tons in emissions from mobile combustion sources since 1990.

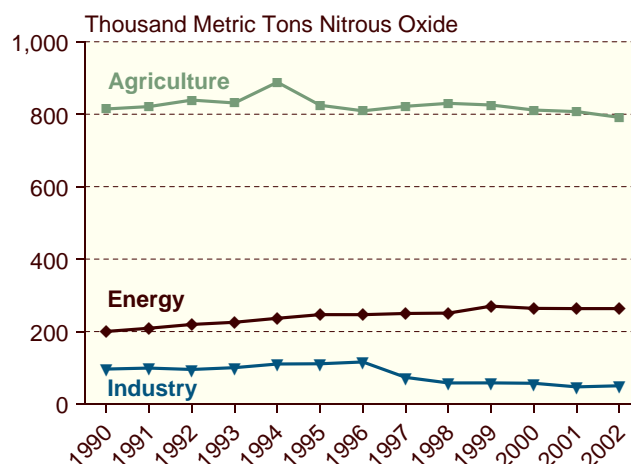
Weighted by global warming potential, total nitrous oxide emissions in 2002 were equivalent to 333.1 million metric tons carbon dioxide, or 4.9 percent of total U.S. greenhouse gas emissions. In 2001, total nitrous oxide emissions were equivalent to 336.8 million metric tons of carbon dioxide, or 4.9 percent of total U.S. greenhouse gas emissions.

Sources of U.S. nitrous oxide emissions include energy use, agriculture, waste management, and industrial processes. The largest component of U.S. anthropogenic nitrous oxide emissions is emissions from agricultural activities, representing 70.3 percent of the total. Nitrogen fertilization of agricultural soils represents 73.7 percent of emissions from agricultural activities. Most of the remainder is from the handling of animal waste in managed systems. Small quantities of nitrous oxide are also released from the burning of crop residues. Estimated emissions of nitrous oxide from agricultural sources were 791 thousand metric tons (or 234.2 million metric tons carbon dioxide equivalent) in 2002, 2.0 percent below 2001 levels and 2.8 percent below 1990 levels (Figure 4).

There are large uncertainties connected with the emissions consequences of adding nitrogen to agricultural soils. Models used for estimation are based on limited sources of experimental data.⁶⁵ The uncertainty increases when moving from emissions associated with animal manure to soil mineralization and atmospheric deposition, where both estimating emissions and partitioning emissions between anthropogenic and biogenic sources become increasingly difficult.

The second-largest source of anthropogenic nitrous oxide emissions is energy consumption, which includes mobile source combustion from passenger cars, buses,

Figure 4. U.S. Emissions of Nitrous Oxide by Source, 1990-2002



Source: Estimates presented in this chapter.

⁶⁵Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.87-4.100, web site www.ipcc.ch/pub/guide.htm.

Principal Sources of U.S. Anthropogenic Nitrous Oxide Emissions, 1990-2002

Source	Thousand Metric Tons Nitrous Oxide		Percent Change	
	1990	2002	1990-2002	2001-2002
Energy	200	263	31.5%	*
Agriculture	814	791	-2.8%	-2.0%
Industrial	96	50	-47.8%	6.5%

*Less than 0.05 percent.

motorcycles, and trucks and stationary source combustion from commercial, residential, industrial, and electric power sector energy use. Energy use was responsible for the release of 263 thousand metric tons of nitrous oxide or 78.0 million metric tons carbon dioxide equivalent in 2002 (23.4 percent of total U.S. nitrous oxide emissions), only slightly (less than 0.05 percent) lower than in 2001 but 31.5 percent higher than in 1990. Industrial production of adipic and nitric acid, which releases nitrous oxide as a byproduct, accounted for emissions of 50 thousand metric tons of nitrous oxide or 14.9 million metric tons carbon dioxide equivalent in 2002 (4.5 percent of total U.S. nitrous oxide emissions), a 6.5-percent increase from 2001 levels and a 47.8-percent decrease from 1990 levels. The increase in emissions from this source in 2002 is a result of increased production of both adipic acid and nitric acid by 86 and 336 thousand metric tons, respectively, compared with compared with 2001 (10.3 and 4.7 percent, respectively). The large decline in emissions of nitrous oxide from adipic acid production since 1990 is a result of the implementation of emissions control technology at three of the four adipic acid plants operating in the United States.

Energy Use

U.S. Nitrous Oxide Emissions from Energy, 1990-2002

Estimated 2002 Emissions (Thousand Metric Tons Nitrous Oxide)	263
Change Compared to 2001 (Thousand Metric Tons Nitrous Oxide)	*
Change from 2001 (Percent)	**
Change Compared to 1990 (Thousand Metric Tons Nitrous Oxide)	63
Change from 1990 (Percent)	31.5%

*Less than 0.5 thousand metric tons.

**Less than 0.05 percent.

The energy use category includes nitrous oxide emissions from both mobile and stationary sources as byproducts of fuel combustion. Estimated 2002 energy-related emissions were 263 thousand metric tons, or 23.4 percent of total U.S. anthropogenic nitrous oxide emissions (Table 23). Emissions from energy use are dominated by mobile combustion (81.4 percent of nitrous oxide emissions from energy use in 2002).

Mobile Combustion

Nitrous oxide emissions from mobile source combustion in 2002 were 214 thousand metric tons or 63.5 million metric tons carbon dioxide equivalent, a decrease of 0.2 thousand metric tons nitrous oxide or 0.1 million metric tons carbon dioxide equivalent (0.1 percent) from 2001 levels (Table 24). In addition to emissions from passenger cars and light-duty trucks, emissions from air, rail, and marine transportation and from farm and construction equipment are also included in the estimates. Motor vehicles are the source of 94.3 percent of nitrous oxide emissions from mobile combustion (Table 24).

Nitrous oxide emissions from motor vehicles are caused primarily by the conversion of nitrogen oxides (NO_x) into nitrous oxide (N_2O) by vehicle catalytic converters. The normal operating temperature of catalytic converters is high enough to cause the thermal decomposition of nitrous oxide. Consequently, it is probable that nitrous oxide emissions result primarily from "cold starts" of motor vehicles and from catalytic converters that are defective or operating under abnormal conditions. This implies that the primary determinant of the level of emissions is motor vehicle operating conditions; however, different types of catalytic converters appear to differ systematically in their emissions, and emissions probably vary with engine size. Thus, emissions also depend on the "mix" of vehicle age and type on the road.

Nitrous oxide emissions from mobile sources grew rapidly between 1990 and 1995 due to increasing motor vehicle use, the shifting composition of the light-duty vehicle fleet toward light trucks that have lower fuel economy and higher per-mile emission factors, and the gradual replacement of low emitting pre-1983 vehicles that did not use catalytic converters with higher emitting post-1983 vehicles that do use catalytic converters. This growth moderated between 1995 and 1999 due to the introduction of more advanced, lower-emitting catalytic converters. After peaking in 1999, emissions have declined slowly as vehicle turnover has led to a fleet dominated by the more advanced catalytic converters.

Stationary Combustion

In 2002, estimated nitrous oxide emissions from stationary combustion sources were 49 thousand metric tons or

14.5 million metric tons carbon dioxide equivalent, 0.3 percent higher than in 2001 and 9.8 percent higher than in 1990 (Table 25). The emissions increase from this source between 1990 and 2002 can be attributed principally to coal-fired electricity generation, which grew in response to the growing demand for electricity and lower costs and improved availability at coal-fired power plants. Coal-fired combustion systems produced 63.6 percent of the 2002 emissions of nitrous oxide from stationary combustion. During combustion, nitrous oxide is produced as a result of chemical interactions between nitrogen oxides (mostly NO_2) and other combustion products. With most conventional stationary combustion systems, high temperatures destroy almost all nitrous oxide, limiting the quantity that escapes; therefore, emissions from these systems typically are low.

Agriculture

U.S. Nitrous Oxide Emissions from Agriculture, 1990-2002

Estimated 2002 Emissions (Thousand Metric Tons Nitrous Oxide)	791
Change Compared to 2001 (Thousand Metric Tons Nitrous Oxide)	-16
Change from 2001 (Percent)	-2.0%
Change Compared to 1990 (Thousand Metric Tons Nitrous Oxide)	-23
Change from 1990 (Percent)	-2.8%

Nitrous oxide emissions from agricultural activities fell by 2.8 percent between 1990 and 2002. Agricultural activities were responsible for 70.3 percent of U.S. nitrous oxide emissions in 2002, roughly the same percentage that agricultural practices contribute to nitrous oxide emissions globally.⁶⁶ Nitrogen fertilization of agricultural soils accounted for 73.7 percent of U.S. agricultural emissions of nitrous oxide (Table 23). Nearly all the remaining agricultural emissions can be traced to the management of the solid waste of domesticated animals. The disposal of crop residues by burning also produces nitrous oxide that is released into the atmosphere; however, the amount is relatively minor, at 2 thousand metric tons or 0.2 percent of total U.S. emissions of nitrous oxide from agricultural sources in 2002.

Nitrogen Fertilization of Agricultural Soils

EIA estimates that a total of 583 thousand metric tons of nitrous oxide (or 172.5 million metric tons carbon dioxide equivalent) was released into the atmosphere as a result of direct and indirect emissions associated with fertilization practices in 2002 (Table 26). Estimated emissions decreased by 2.5 percent compared with 2001 levels and were 3.4 percent lower than in 1990. Nitrous oxide emissions from the application of nitrogen-based fertilizers and biological fixation in crops accounted for 57.3 percent of total nitrous oxide emissions from this source during 2002.

Nitrogen uptake and nitrous oxide emissions occur naturally as a result of nitrification and denitrification processes in soil and crops, generally through bacterial action. When nitrogen compounds are added to the soil, bacterial action is stimulated, and emissions generally increase, unless the application precisely matches plant uptake and soil capture.⁶⁷ Nitrogen may be added to the soil by synthetic or organic fertilizers, nitrogen-fixing crops, and crop residues. Nitrogen-rich soils, called "histosols," may also stimulate emissions. Adding excess nitrogen to the soil also enriches ground and surface waters, such as rivers and streams, which generate indirect emissions of nitrous oxide. Additional indirect emissions occur from "atmospheric deposition," in which soils emit other nitrogen compounds that react to form nitrous oxide in the atmosphere.

Crop Residue Burning

In 2002, estimated emissions of nitrous oxide from crop residue burning were 2 thousand metric tons (or 0.5 million metric tons carbon dioxide equivalent), down by less than 0.5 thousand metric tons nitrous oxide (4.8 percent) from 2001 levels (Table 23). The small decrease is mainly attributable to decreased corn and soybean production. Emissions from this source remain very small, at 0.2 percent of all U.S. nitrous oxide emissions. When crop residues are burned, the incomplete combustion of agricultural waste results in the production of nitrous oxide, as well as methane (discussed in Chapter 3).

Solid Waste of Domesticated Animals

Estimated 2002 nitrous oxide emissions from animal waste management were 207 thousand metric tons (or 61.2 million metric tons carbon dioxide equivalent), down by 0.5 percent from 2001 levels and 1.3 percent lower than 1990 levels (Table 27), making animal waste the second-largest U.S. agricultural source of nitrous oxide emissions, after nitrogen fertilization of soils.

⁶⁶A.R. Mosier, "Nitrous Oxide Emissions from Agricultural Soils," in A.R. van Amstel (ed.), *International IPCC Workshop Proceedings: Methane and Nitrous Oxide, Methods in National Emissions Inventories and Options for Control* (Bilthoven, Netherlands: RIVM, 1993), p. 277.

⁶⁷A.F. Bouwman, "Exchange of Greenhouse Gases Between Terrestrial Ecosystems and the Atmosphere," in A.F. Bouwman (ed.), *Soils and the Greenhouse Effect* (New York, NY: John Wiley and Sons, 1990).

Nitrous oxide emissions from animal waste are dominated by emissions from cattle waste, which account for 92.6 percent of emissions from the solid waste of domesticated animals.

Nitrous oxide is released as part of the microbial denitrification of animal manure. The total volume of nitrous oxide emissions is a function of animal size and manure production, the amount of nitrogen in the animal waste, and the method of managing the animal waste. Waste managed by a solid storage or pasture range method may emit 20 times more nitrous oxide per unit of nitrogen content than does waste managed in anaerobic lagoon and liquid systems. Generally, solid waste from feedlot beef cattle is managed with the solid storage or pasture range method, accounting for the majority of nitrous oxide emissions. Solid waste from swine is generally managed in anaerobic lagoons and other liquid systems. Anaerobic digestion yields methane emissions but only negligible amounts of nitrous oxide. Thus, changes in estimated emissions result primarily from changes in cattle populations. For example, beef cattle populations grew during the first half of the 1990s, leading to higher emissions through 1995, but have since declined slowly, lowering emissions nearly to 1991 levels.

Waste Management

U.S. Nitrous Oxide Emissions from Waste Management, 1990-2002	
Estimated 2002 Emissions (Thousand Metric Tons Nitrous Oxide)	20
Change Compared to 2001 (Thousand Metric Tons Nitrous Oxide)	*
Change from 2001 (Percent)	1.4%
Change Compared to 1990 (Thousand Metric Tons Nitrous Oxide)	4
Change from 1990 (Percent)	22.1%
*Less than 0.5 thousand metric tons.	

Nitrous oxide emissions from waste management are estimated at 20 thousand metric tons (or 6.0 million metric tons carbon dioxide equivalent) for 2002, 1.8 percent of all U.S. anthropogenic nitrous oxide emissions (Table 23). During 2002, emissions from human sewage in wastewater were responsible for 95.7 percent of the estimated emissions from this source, and the remainder

was associated with waste combustion. Estimated emissions from waste management increased by 1.4 percent between 2001 and 2002 and by 22.1 percent between 1990 and 2002. Because of the lack of reliable data and an effective estimation method, no estimate of emissions from industrial wastewater was calculated, leaving estimated emissions from waste management lower than they otherwise would be had a viable estimation method been available.

Waste Combustion

In 2002, estimated nitrous oxide emissions from waste combustion were 1 thousand metric tons, down 5.6 percent from 2001 levels and 3.6 percent above 1990 levels. Data on the amount of waste generated in the United States in 2002 were not available in time for this report; therefore, EIA scaled the 2002 estimates for waste combustion to the growth in U.S. gross domestic product. The share of waste burned is estimated to have been unchanged from 2001 to 2002, and the total volume of waste generated is estimated to have increased by 9.0 percent. The total volume of waste generated in the United States increased by 58.2 percent between 1990 and 2002; however, the share of waste burned in 2002 was just 7.5 percent, compared with 11.5 percent in 1990.⁶⁸

Human Sewage in Wastewater

In 2002, nitrous oxide emissions from wastewater were 19 thousand metric tons (or 5.7 million metric tons carbon dioxide equivalent), a 1.3-percent increase from 2001 levels and a 23.7-percent increase from the 1990 level (Table 23). Estimates of nitrous oxide emissions from human waste are scaled to population size and per capita protein intake. U.S. population has grown by 13.7 percent since 1990. U.S. per capita protein intake rose steadily between 1990 and 1999, before declining slightly in 2000, 2001, and 2002. Today, U.S. per capita protein intake is 6.5 percent above 1990 levels. Data on protein intake are taken from the United Nations Food and Agriculture Organization (FAO).⁶⁹

Nitrous oxide is emitted from wastewater that contains nitrogen-based organic materials, such as those found in human or animal waste. Two natural processes—nitrification and denitrification—combine to produce nitrous oxide. Nitrification, an aerobic process, converts ammonia into nitrate; denitrification, an anaerobic process, converts nitrate to nitrous oxide. Factors that influence the amount of nitrous oxide generated from wastewater include temperature, acidity, biochemical oxygen demand (BOD),⁷⁰ and nitrogen concentration.

⁶⁸“Nationwide Survey: The State of Garbage in America 1999,” *Biocycle* (April 2000). Waste streams were estimated for 2002 by scaling to economic growth, and the share of waste combusted was held constant at the 2001 level.

⁶⁹Food and Agriculture Organization of the United Nations, statistical databases, web site <http://apps.fao.org>.

⁷⁰Biochemical oxygen demand is a measure of the organic content within the wastewater that is subject to decomposition.

Industrial Sources

U.S. Nitrous Oxide Emissions from Industrial Sources, 1990-2002

Estimated 2002 Emissions (Thousand Metric Tons Nitrous Oxide)	50
Change Compared to 2001 (Thousand Metric Tons Nitrous Oxide)	3
Change from 2001 (Percent)	6.5%
Change Compared to 1990 (Thousand Metric Tons Nitrous Oxide)	-46
Change from 1990 (Percent)	-47.8%

Emissions of nitrous oxide from industrial sources were 50 thousand metric tons (or 14.9 million metric tons carbon dioxide equivalent) in 2002, an increase of 3 thousand metric tons or 0.9 million metric tons carbon dioxide equivalent (6.5 percent) from 2001 and a decrease of 46 thousand metric tons or 13.7 million metric tons carbon dioxide equivalent (47.8 percent) since 1990. Nitrous oxide is emitted as a byproduct of certain chemical production processes. Table 28 provides estimates of emissions from the production of adipic acid and nitric acid, the two principal known sources.

Adipic Acid Production

Emissions from adipic acid production rose from 12 thousand metric tons of nitrous oxide (or 3.5 million metric tons carbon dioxide equivalent) in 2001 to 13 thousand metric tons (or 3.9 million metric tons carbon dioxide equivalent) in 2002—an increase of 10.3 percent. As discussed below, emissions from this source have been in the range of 12 to 14 thousand metric tons of nitrous oxide per year since 1998.

Adipic acid is a fine white powder that is used primarily in the manufacture of nylon fibers and plastics, such as carpet yarn, clothing, and tire cord. Other uses of adipic acid include production of plasticizer for polyvinyl chloride and polyurethane resins, lubricants, insecticides, and dyes. In the United States, three companies, which operate a total of four plants, manufacture adipic acid by oxidizing a ketone-alcohol mixture with nitric acid. Nitrous oxide is an intrinsic byproduct of this chemical

reaction. For every metric ton of adipic acid produced, 0.3 metric ton of nitrous oxide is created.⁷¹ Between 1990 and 1996, emissions from adipic acid manufacture grew by 23.2 percent, reaching 70 thousand metric tons of nitrous oxide (or 20.7 million metric tons carbon dioxide equivalent) before dropping sharply to 27 thousand metric tons of nitrous oxide (or 7.8 million metric tons carbon dioxide equivalent) in 1997 (Table 28).

Beginning in 1996, two of the four plants that manufacture adipic acid controlled emissions by thermally decomposing the nitrous oxide. This technique eliminates 98 percent of potential nitrous oxide emissions from the process.⁷² During the first quarter of 1997, a third plant installed emissions controls, increasing the share of adipic acid production employing emissions abatement controls from 74.1 percent in 1996 to 91.6 percent in 1997. In 1998, with emissions controls in place for the full year, 97.4 percent of emissions from U.S. adipic acid production were controlled.⁷³ Estimated emissions of nitrous oxide from uncontrolled adipic acid production decreased from 22 thousand metric tons in 1997 to 8 thousand metric tons in 2002, and 2002 emissions of nitrous oxide from controlled plants remained relatively constant at 5 thousand metric tons. With the share of adipic acid production employing abatement controls now at nearly 100 percent, future changes in nitrous oxide emissions from this source are expected to result primarily from changes in plant production levels in response to market demand.

Nitric Acid Production

The 6.8 million metric tons of nitric acid manufactured in 2002 resulted in estimated emissions of 37 thousand metric tons of nitrous oxide, equivalent to 11.0 million metric tons of carbon dioxide (Table 28). This estimate was 5.2 percent higher than 2001 levels and 6.1 percent lower than 1990 levels. The emissions factor used to estimate nitrous oxide emissions from the production of nitric acid was based on measurements at a single DuPont plant, which indicated an emissions factor of 2 to 9 grams of nitrous oxide emitted per kilogram of nitric acid manufactured, suggesting an uncertainty of plus or minus 75 percent in the emissions estimate.⁷⁴ Nitric acid, a primary ingredient in fertilizers, usually is manufactured by oxidizing ammonia (NH₃) with a platinum catalyst. Nitrous oxide emissions are a direct result of the oxidation.

⁷¹M.H. Thiemens and W.C. Trogler, "Nylon Production: An Unknown Source of Atmospheric Nitrous Oxide," *Science*, Vol. 251, No. 4996 (February 1991).

⁷²Radian Corporation, *Nitrous Oxide Emissions From Adipic Acid Manufacturing* (Rochester, NY, January 1992), p. 10.

⁷³R.A. Reimer, R.A. Parrett, and C.S. Slaten, "Abatement of N₂O Emissions Produced in Adipic Acid," in *Proceedings of the Fifth International Workshop on Nitrous Oxide Emissions* (Tsukuba, Japan, July 1992).

⁷⁴Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris France, 1997), p 2.18, web site www.ipcc.ch/pub/guide.htm.

Table 23. Estimated U.S. Emissions of Nitrous Oxide, 1990-2002

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Nitrous Oxide													
Energy													
Mobile Combustion	156	165	175	180	190	200	198	201	203	221	214	215	214
Stationary Combustion.	45	44	45	46	46	47	49	49	48	49	50	49	49
Total	200	209	220	226	237	247	247	250	251	270	264	263	263
Agriculture													
Nitrogen Fertilization of Soils	604	609	624	613	667	601	587	604	616	613	601	598	583
Crop Residue Burning	2	2	2	1	2	2	2	2	2	2	2	2	2
Solid Waste of Domesticated Animals . .	209	211	214	216	220	222	220	216	213	211	209	208	207
Total	814	821	839	831	888	825	809	822	830	826	812	807	791
Waste Management													
Waste Combustion.	1	1	1	1	1	1	1	1	1	1	1	1	1
Human Sewage in Wastewater	16	16	16	16	17	17	17	17	18	18	19	19	19
Total	17	17	17	17	18	18	18	18	18	19	20	20	20
Industrial Processes	96	99	95	100	110	111	116	74	58	58	57	47	50
Total	1,128	1,146	1,171	1,174	1,253	1,200	1,190	1,164	1,158	1,173	1,153	1,138	1,125
Million Metric Tons Carbon Dioxide Equivalent													
Energy													
Mobile Combustion	46.1	48.9	51.7	53.3	56.3	59.2	58.6	59.5	60.0	65.5	63.2	63.5	63.5
Stationary Combustion.	13.2	13.1	13.3	13.5	13.7	13.8	14.4	14.5	14.3	14.5	14.9	14.4	14.5
Total	59.3	61.9	65.0	66.8	70.1	73.0	73.0	74.0	74.3	80.0	78.2	78.0	78.0
Agriculture													
Nitrogen Fertilization of Soils	178.6	180.1	184.6	181.6	197.4	178.0	173.9	178.9	182.2	181.4	177.7	176.9	172.5
Crop Residue Burning	0.5	0.5	0.5	0.4	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.6	0.5
Solid Waste of Domesticated Animals . .	62.0	62.5	63.2	64.0	65.0	65.7	65.2	63.9	62.9	62.4	61.9	61.5	61.2
Total	241.1	243.1	248.3	246.0	263.0	244.1	239.6	243.3	245.7	244.4	240.2	238.9	234.2
Waste Management													
Waste Combustion.	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3
Human Sewage in Wastewater	4.6	4.8	4.8	4.9	5.0	5.0	5.1	5.1	5.2	5.4	5.6	5.6	5.7
Total	4.9	5.0	5.1	5.1	5.3	5.3	5.4	5.4	5.4	5.7	5.9	5.9	6.0
Industrial Processes	28.6	29.4	28.2	29.7	32.7	32.9	34.3	21.8	17.2	17.2	17.0	14.0	14.9
Total	333.8	339.3	346.7	347.6	371.0	355.3	352.3	344.4	342.6	347.2	341.2	336.8	333.1

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002). Totals may not equal sum of components due to independent rounding.

Sources: Estimates presented in this chapter. Emissions calculations based on Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.81-4.94, web site www.ipcc.ch/pub/guide.htm; and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2001*, EPA-430-R-03-004 (Washington, DC, April 2003), web site <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2003.html>.

Table 24. U.S. Nitrous Oxide Emissions from Mobile Combustion, 1990-2002

Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Nitrous Oxide													
Motor Vehicles													
Passenger Cars	99	107	115	112	111	108	109	109	110	112	108	107	106
Buses	*	*	*	*	*	*	*	*	*	*	*	*	*
Motorcycles.....	*	*	*	*	*	*	*	*	*	*	*	*	*
Light-Duty Trucks	38	40	41	50	60	72	69	71	72	88	84	87	88
Other Trucks.....	6	6	6	6	7	7	7	8	8	8	8	8	8
Total	144	153	162	168	178	188	185	189	190	209	200	202	203
Other Mobile Sources.....	12	12	12	12	12	12	13	12	12	13	13	12	12
Total	156	165	175	180	190	200	198	201	203	221	214	215	214
Million Metric Tons Carbon Dioxide Equivalent													
Motor Vehicles													
Passenger Cars	29	32	34	33	33	32	32	32	32	33	32	32	31
Buses	0	0	0	0	0	0	0	0	0	0	0	0	0
Motorcycles.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Light-Duty Trucks	11	12	12	15	18	21	20	21	21	26	25	26	26
Other Trucks.....	2	2	2	2	2	2	2	2	2	2	2	2	2
Total	42	45	48	50	53	56	55	56	56	62	59	60	60
Other Mobile Sources.....	4	4	4	4	4	4	4	4	4	4	4	4	3
Total	46	49	52	53	56	59	59	59	60	65	63	64	63

*Less than 500 metric tons of nitrous oxide.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002). Totals may not equal sum of components due to independent rounding.

Sources: Calculations based on vehicle miles traveled from U.S. Department of Transportation, *Federal Highway Statistics* (various years), Table VM-1, and current year preliminary estimates calculated using growth rates from EIA, *Short-Term Energy Outlook* (various years). Other Mobile Sources calculations based on Oak Ridge National Laboratory, *Transportation Energy Data Book*; EIA, *Fuel Oil and Kerosene Sales*, *State Energy Data Report*, and *Petroleum Supply Annual* (various years). Passenger car and light-duty truck emissions coefficients from U.S. Environmental Protection Agency, Office of Air and Radiation, *Emissions of Nitrous Oxide From Highway Mobile Sources: Comments on the Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-1996*, EPA-420-R-98-009 (Washington DC, August 1998). Emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 1.64-1.68, web site www.ipcc.ch/pub/guide.htm.

Table 25. U.S. Nitrous Oxide Emissions from Stationary Combustion, 1990-2002

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Nitrous Oxide													
Residential													
Coal	*	*	*	*	*	*	*	*	*	*	*	*	*
Fuel Oil ^a	1	1	1	1	1	1	1	1	1	1	1	1	1
Natural Gas	*	*	*	*	*	*	1	*	*	*	*	*	*
Wood	2	2	3	2	2	2	2	2	2	2	2	2	1
Total.....	4	4	4	4	3	4	4	3	3	3	3	3	3
Commercial													
Coal	*	*	*	*	*	*	*	*	*	*	*	*	*
Fuel Oil ^a	1	1	1	*	*	*	*	*	*	*	*	*	*
Natural Gas	*	*	*	*	*	*	*	*	*	*	*	*	*
Wood	*	*	*	*	*	*	*	*	*	*	*	*	*
Total.....	1	1	1	1	1	1	1	1	1	1	1	1	1
Industrial													
Coal	4	4	3	3	3	3	3	3	3	3	3	3	3
Fuel Oil ^a	5	5	5	5	5	5	5	6	5	6	6	6	6
Natural Gas	1	1	1	1	1	1	1	1	1	1	1	1	1
Wood	6	6	6	6	6	7	7	7	6	6	6	6	6
Total.....	10	9	10	9	10	10	10	10	10	10	9	10	9
Electric Power													
Coal	23	23	23	24	24	25	26	27	27	27	28	28	28
Fuel Oil ^a	1	1	1	1	1	*	*	1	1	1	1	1	1
Natural Gas	*	*	*	*	*	*	*	*	*	*	1	1	1
Wood	1	*	1	1	1	*	1	1	1	1	1	*	1
Total.....	24	24	25	26	26	26	27	28	29	29	30	30	30
Fuel Totals													
Coal	27	27	27	28	28	28	30	30	30	30	32	31	31
Fuel Oil^a	7	7	7	7	7	7	7	7	7	8	8	8	8
Natural Gas	2	2	2	2	2	2	2	2	2	2	2	2	2
Wood	9	9	9	9	9	10	10	9	9	9	9	8	8
Total.....	45	44	45	46	46	47	49	49	48	49	50	49	49

See notes and sources at end of table.

Table 25. U.S. Nitrous Oxide Emissions from Stationary Combustion, 1990-2002 (Continued)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Carbon Dioxide Equivalent													
Residential													
Coal	11	10	10	10	9	7	7	7	5	6	5	5	5
Fuel Oil ^a	251	249	255	259	254	247	266	255	235	263	279	275	272
Natural Gas	129	133	137	145	142	142	153	145	133	138	146	140	144
Wood	677	714	751	638	626	694	693	504	451	482	504	474	408
Total	1,067	1,106	1,154	1,052	1,030	1,090	1,119	912	824	889	934	894	828
Commercial													
Coal	54	49	49	50	49	49	51	54	38	43	38	40	40
Fuel Oil ^a	170	162	153	139	141	131	134	126	118	118	135	132	132
Natural Gas	77	80	82	84	85	88	92	94	88	89	94	89	91
Wood	45	48	51	54	54	54	58	57	56	61	62	48	48
Total	346	339	335	326	328	322	335	330	300	311	329	309	311
Industrial													
Coal	1,131	1,064	1,030	1,023	1,028	1,020	995	977	914	893	906	929	872
Fuel Oil ^a	1,478	1,426	1,532	1,503	1,572	1,538	1,617	1,659	1,628	1,678	1,629	1,647	1,667
Natural Gas	242	245	255	259	261	274	283	283	279	268	271	247	242
Wood	1,680	1,643	1,702	1,729	1,841	1,924	1,961	2,017	1,867	1,887	1,906	1,681	1,753
Total	2,851	2,736	2,817	2,785	2,860	2,832	2,895	2,920	2,820	2,839	2,806	2,823	2,781
Electric Power													
Coal	6,770	6,772	6,862	7,166	7,193	7,278	7,680	7,878	8,008	8,034	8,426	8,205	8,328
Fuel Oil ^a	228	214	177	201	189	135	146	166	233	216	204	229	162
Natural Gas	94	97	100	101	114	123	110	118	133	140	151	153	161
Wood	150	147	163	175	177	146	161	160	160	161	156	147	157
Total	7,242	7,229	7,302	7,642	7,673	7,682	8,097	8,321	8,534	8,551	8,937	8,733	8,809
Fuel Totals													
Coal	7,965	7,895	7,951	8,248	8,278	8,354	8,733	8,916	8,965	8,976	9,375	9,179	9,245
Fuel Oil^a	2,128	2,051	2,117	2,102	2,155	2,051	2,163	2,205	2,214	2,275	2,247	2,282	2,232
Natural Gas	541	555	575	589	601	627	638	640	633	634	661	629	638
Wood	2,552	2,551	2,668	2,595	2,697	2,818	2,873	2,738	2,534	2,591	2,628	2,350	2,366
Total	13,187	13,051	13,310	13,534	13,731	13,850	14,406	14,499	14,345	14,476	14,911	14,441	14,482

*Less than 500 metric tons nitrous oxide.

P = preliminary data.

^aFuel oil use in the residential sector consists of distillate fuel only. In the other sectors it includes both distillate and residual fuel oil.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002). Totals may not equal sum of components due to independent rounding.

Sources: Emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), p. 1.50, web site www.ipcc.ch/pub/guide.htm. Energy consumption data from Energy Information Administration, *State Energy Data Report 1998*, DOE/EIA-0214(98) (Washington, DC, September 2002); and *Monthly Energy Review*, DOE/EIA-0035(2003/08) (Washington, DC, August 2003).

Table 26. U.S. Nitrous Oxide Emissions from Nitrogen Fertilization of Agricultural Soils, 1990-2002
(Thousand Metric Tons Nitrous Oxide)

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Nitrous Oxide													
Direct Emissions													
Nitrogen Fertilizers	179	182	183	193	195	173	159	159	161	161	154	150	153
Animal Manure	4	4	5	5	5	5	4	4	4	4	4	4	4
Crop Residues	94	91	105	86	113	94	106	114	117	113	116	116	110
Soil Mineralization	10	10	10	10	10	10	10	10	10	11	11	11	11
Biological Fixation in Crops . . .	171	174	173	165	187	179	178	187	194	193	191	195	181
Sewage Sludge	1	1	1	1	1	1	1	1	1	1	1	1	2
Total Direct Emissions	459	462	476	458	510	461	459	475	486	482	476	476	459
Indirect Emissions													
Soil Leaching	123	125	126	132	134	119	109	110	110	111	106	103	105
Atmospheric Deposition	22	22	22	23	24	21	20	20	20	20	19	18	19
Total Indirect Emissions . . .	144	147	148	155	157	140	129	129	130	130	125	122	124
Total	604	609	624	613	667	601	587	604	616	613	601	598	583
Million Metric Tons Carbon Dioxide Equivalent													
Direct Emissions													
Nitrogen Fertilizers	53	54	54	57	58	51	47	47	48	48	46	44	45
Animal Manure	1	1	1	1	1	1	1	1	1	1	1	1	1
Crop Residues	28	27	31	25	33	28	31	34	35	33	34	34	33
Soil Mineralization	3	3	3	3	3	3	3	3	3	3	3	3	3
Biological Fixation in Crops . . .	51	51	51	49	55	53	53	55	57	57	56	58	54
Sewage Sludge	*	*	*	*	*	*	*	*	*	*	*	*	*
Total Direct Emissions	136	137	141	136	151	137	136	141	144	143	141	141	136
Indirect Emissions													
Soil Leaching	36	37	37	39	40	35	32	32	33	33	31	31	31
Atmospheric Deposition	6	7	7	7	7	6	6	6	6	6	6	5	6
Total Indirect Emissions . . .	43	43	44	46	47	41	38	38	38	39	37	36	37
Total	179	180	185	182	197	178	174	179	182	181	178	177	173

*Less than 0.5 million metric tons carbon dioxide equivalent.

P = preliminary data.

Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002). Totals may not equal sum of components due to independent rounding.

Sources: Estimates presented in this chapter. Emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.89-4.107, web site www.ipcc.ch/pub/guide.htm. Total nitrogen content of U.S. commercial fertilizer consumption—1988-1994, Tennessee Valley Authority; 1995-2002, Association of American Plant Food Control Officials, *Commercial Fertilizers* (Washington, DC, various years). Manure application based on cattle population data provided by the U.S. Department of Agriculture, National Agricultural Statistics Service, web sites www.usda.gov/nass/pubs/histdata.htm and www.nass.usda.gov/ipedb/. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990* (Washington, DC, April 1993), p. 6-8. Manure production and waste management systems used from L.M. Safley, M.E. Casada et al., *Global Methane Emissions From Livestock and Poultry Manure* (Washington, DC, February 1992), and U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2001*, EPA-430-R-03-004 (Washington, DC, April 2003), web site <http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2003.html>.

Table 27. U.S. Nitrous Oxide Emissions from Solid Waste of Domesticated Animals, 1990-2002

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Nitrous Oxide													
Cattle.....	194	196	198	200	204	206	205	200	197	195	194	192	192
Swine.....	5	5	5	5	6	5	5	6	6	6	5	6	5
Poultry.....	3	3	3	4	4	4	4	4	4	4	4	4	4
Sheep.....	3	3	3	3	3	3	3	2	2	2	2	2	2
Goats.....	1	1	1	1	1	1	1	1	1	1	1	1	1
Horses.....	2	2	2	2	2	2	2	2	2	2	3	3	3
Total.....	209	211	214	216	220	222	220	216	213	211	209	208	207
Million Metric Tons Carbon Dioxide Equivalent													
Cattle.....	58	58	59	59	60	61	61	59	58	58	57	57	57
Swine.....	1	2	2	2	2	2	2	2	2	2	2	2	2
Poultry.....	1	1	1	1	1	1	1	1	1	1	1	1	1
Sheep.....	1	1	1	1	1	1	1	1	1	1	1	1	1
Goats.....	*	*	*	*	*	*	*	*	*	*	*	*	*
Horses.....	1	1	1	1	1	1	1	1	1	1	1	1	1
Total.....	62	62	63	64	65	66	65	64	63	62	62	61	61

*Less than 0.5 million metric tons carbon dioxide equivalent.

P = preliminary data.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Estimates presented in this chapter. Nitrogen content of waste by species, manure management systems, and emissions coefficients from Intergovernmental Panel on Climate Change, *Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3 (Paris, France, 1997), pp. 4.89-4.107, web site www.ipcc.ch/pub/guide.htm. Population data for horses and goats extrapolated from U.S. Department of Commerce, Bureau of the Census, *Census of Agriculture* (1982, 1987, 1992, and 1997). All other animal populations from U.S. Department of Agriculture, National Agricultural Statistics Service, web sites www.usda.gov/nass/pubs/histdata.htm and www.nass.usda.gov/ipedb/. Typical animal sizes from U.S. Environmental Protection Agency, Office of Air and Radiation, *Anthropogenic Methane Emissions in the United States: Estimates for 1990* (Washington, DC, April 1993), p. 6-8. Cattle sizes adjusted by annual slaughter weight from U.S. Department of Agriculture, National Agricultural Statistics Service.

Table 28. U.S. Nitrous Oxide Emissions from Industrial Sources, 1990-2002

Source	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	P2002
Thousand Metric Tons Nitrous Oxide													
Adipic Acid													
Controlled Sources.....	3	4	3	3	4	4	4	5	5	5	5	5	5
Uncontrolled Sources.....	54	56	52	56	63	63	66	22	7	8	9	7	8
Total.....	57	60	55	59	67	67	70	27	12	14	14	12	13
Nitric Acid.....	40	40	41	41	43	44	46	47	46	45	43	35	37
Total Known Industrial Sources....	96	99	95	100	110	111	116	74	58	58	57	47	50
Million Metric Tons Carbon Dioxide Equivalent													
Adipic Acid													
Controlled Sources.....	1	1	1	1	1	1	1	1	1	2	2	1	2
Uncontrolled Sources.....	16	17	15	17	19	19	20	6	2	2	3	2	2
Total.....	17	18	16	18	20	20	21	8	3	4	4	4	4
Nitric Acid.....	12	12	12	12	13	13	14	14	14	13	13	10	11
Total Known Industrial Sources....	29	29	28	30	33	33	34	22	17	17	17	14	15

P = preliminary data.

Note: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002). Totals may not equal sum of components due to independent rounding.

Sources: Data sources and methods documented in Energy Information Administration, *Documentation: Emissions of Greenhouse Gases in the United States 2002* (to be published).

